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Tank Effectiveness
Conqueror, Conway and Charioteer

June 1954

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ARMY OPERATIONAL RESEARCH GROUP

MEMORANDUM NO. E.13

TANK EFFECTIVENESS
CONQUEROR, CONWAY AND CHARIOTEER

Prepared by:- A.V. Longman

ABSTRACT

In AORG Reports Nos. 11/51 and 6/52, values for a measure of Battle Effectiveness have been calculated for a number of past and current tanks. In this paper, results are obtained for three new British tanks, the Conqueror, Conway and Charioteer, when opposed to two Russian tanks, the JS3 and T34/85. Comparative figures are given for the Centurion 3.

Of the British tanks considered in this note, the best performance against the JS3 is given, as might be expected, by the Conqueror, whose Effectiveness is some 20% greater than that of the Centurion 3. This improvement is due primarily to the better performance of the 120 mm gun against the frontal armour of the JS3. The relative Effectiveness of Conqueror and Centurion, is likely to be maintained against any heavier Russian tank. Against the T34/85 the Effectiveness of the Conqueror is no greater than that of the Centurion since both British tanks are very effective against the lighter Russian vehicle.

The Conway is an up-gunned Centurion with a 120 mm gun, and it therefore has the same gun performance as the Conqueror against the front of the JS3. The improvement in gun performance over that of the Centurion has, however, been offset by an increase in vulnerability due to a reduction in armour and an increase in silhouette, and the two tanks have the same Effectiveness against the JS3. At the same time the Effectiveness of the Conway against the T34/85 is some 20% less than that of the Centurion, largely on account of its greater vulnerability. The value of the Conway therefore depends on whether, from tactical considerations, the advantage of being able to defeat the JS3 from the front outweighs the associated disadvantage of increased vulnerability.

Although the Charioteer, an up-gunned Cromwell, mounts the same gun as the Centurion 3, its armour is much lighter and comparison with the Centurion is rather unfair. Nevertheless, it has a high chance of killing the T34/85 and is equivalent to this tank. Against the JS3 it is at a considerable disadvantage, round for round, but its superior rate of fire and switching time more or less offset this disadvantage in an extended action.

The comparisons given above relate to ranges of up to 1,000 yards, where the Effectiveness of the tanks with the 120 mm gun is the same whether they fire APDS or HESH ammunition. At 2,000 yards range the accuracy of each of the British guns firing APDS ammunition is greater than that of the Russian guns, but these in turn are more accurate than the 120 mm firing HESH. As a result, the Effectiveness of British tanks at 2,000 yards is rather greater than that at 1,000 yards when they fire APDS ammunition, but the use of HESH in the 120 mm leads to some reduction in Effectiveness at the longer range.

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CONQUEROR, CONWAY AND CHARIOTEER

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TANK EFFECTIVENESS
CONQUEROR, CONWAY AND CHARIOTEER

Prepared by:- A.V. Longman

INTRODUCTION AND OBJECT

1. Methods for calculating a measure of Tank Effectiveness were described in AORG Reports Nos. 21/50, 11/51 and 6/52, and numerical values of this Effectiveness (E) were presented for a number of past and current tanks. In the present paper, values of E are given for three new British tanks, the Conqueror (FV 214), the Conway (FV 4004) and the Charioteer (FV 4101), when opposed to the Russian tanks JS3 and T34/85. For comparison, figures are also given for the Centurion 3.
2. It should be remembered that E is essentially a measure of relative gun and armour capabilities in battle; it does not take into account all the factors that would be involved in an assessment of overall performance.
3. The numerical method of calculation is basically that described in AORG Report No. 11/51. The following points should, however, be noted :-
 - (a) Whittaker's directional probability variation (d.p.v.) has been used in preference to the elliptical d.p.v. discussed in Report No. 11/51.*
 - (b) A modified formula is used for average rate of fire, which takes into account the time required to switch from one target to another in the tank battle. This formula was established in AORG Report No. 6/52.
4. Little information is available on the actual rates of fire and switching times of the tanks considered under battle conditions. Values of E have therefore been calculated for typical values of these parameters, and have been found to be not unduly sensitive to small variations in the figures assumed. Although these absolute values of E cannot be considered to have a precise significance, the values of Relative Effectiveness quoted are unlikely to be greatly in error.
5. In AORG Report No. 6/52 it was suggested that values of E calculated on the assumption that ranges are known with rangefinder accuracy are the more truly representative of battle Effectiveness. In the results which follow, therefore, it has been assumed that the errors of range assessment have a standard deviation of $19r^2$ yards (where r is the range in thousands of yards), this being a typical figure for the accuracy of a rangefinder. The relevant data on gun performance and errors are presented in an Appendix.

* Attention has been drawn to the presence of a numerical error in Appendix E of Report No. 11/51 which compares these two probability variations. Re-examination of the correct figures shows that Whittaker's d.p.v. in fact agrees well with battle data and is to be preferred. The effect on the numerical values of E previously quoted is small, but full revised figures and a description of a simplified method of calculation will be published in due course.

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RESULTS

6. The measure of Effectiveness of one type of tank when opposed to another depends on the single shot kill probabilities on each side, averaged over all directions of attack in accordance with the d.p.v., and also on the average rates of fire over a number of successive rounds. The appropriate kill probabilities are shown in Table 1(a) for the British guns against the Russian tanks and in Table 1(b) for the Russian guns against the British tanks. Figures are given for two ranges, 1000 and 2000 yards.

Table 1(a)

Performance of British tank guns against Russian tanks

British guns and ammn.	At 1,000 yds		At 2,000 yds	
	v JS3	v T34/85	v JS3	v T34/85
120 mm AFDS	p ₁	.98	.97	.71
	p ₂	.65	.80	.59
	p ₃	.63	.78	.42
120 mm HESH	p ₁	.98	.98	.38
	p ₂	.62	.76	.62
	p ₃	.61	.75	.23
20 pr AFDS Mk 3	p ₁	.95	.94	.65
	p ₂	.47	.79	.44
	p ₃	.45	.75	.28

Note : p₁ = average chance of a hit
 p₂ = average chance of a kill when hit is scored
 p₃ = overall average chance of a kill

Table 1(b)

Performance of Russian tank guns against British tanks

Russian guns and ammn.	v Centurion 3	v Conqueror	v Conway	v Charioteer
122 mm AFCEC p ₁	.97	.98	.99	.96
At 1,000 yds p ₂	.66	.51	.76	.92
p ₃	.64	.50	.75	.88
85 mm AFCEC p ₁	.96	.98	.98	.95
At 1,000 yds p ₂	.33	.33	.57	.90
p ₃	.32	.32	.56	.86
122 mm AFCEC p ₁	.51	.57	.59	.50
At 2,000 yds p ₂	.61	.51	.72	.91
p ₃	.31	.29	.43	.46
85 mm AFCEC p ₁	.50	.55	.56	.49
At 2,000 yds p ₂	.27	.30	.31	.83
p ₃	.13	.17	.18	.40

Note: P₁, P₂, P₃ have the same meanings as in Table 1(a).

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British
Conqueror 120 mm AFDS
Conqueror 120 mm HESH
Conway (1) 120 mm AFDS
Conway (2) 120 mm HESH
Charioteer 20 pr AFDS
Centurion 20 pr AFDS

Note

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7. It will be seen that at 1000 yards the chance of hit (p_1) is never less than 94%, and that the overall kill probability (p_3) closely resembles the chance that a round which scores a hit will be lethal (p_2). At 2000 yards there is a small reduction (except for HESH ammunition) in the chance that a round which hits will be lethal, but it will be seen that the considerable drop in overall kill chance is mainly a reflection of the reduction in the chance of hit.

8. In this connection there is one general point that might be mentioned. In circumstances where the first round chance of hit and kill is high (e.g. at ranges up to about 1000 yds in the present context) the ability to fire first is clearly of prime importance in the individual engagement: this ability however depends in general on the tactical situation prevailing at the time, rather than on the mechanical capabilities of the tank. In deriving a measure of inherent weapon capabilities, therefore, it would be unreasonable to give either side a consistent advantage in this sense: in the measure of Effectiveness used here it has been assumed that the opportunity of firing first will, all in all, be presented as often to one side as to the other. The measure thus represents an overall average value for the relative gun and armour capabilities of opposing tanks, and does not claim to predict the results of individual engagements.

9. Table 2 below gives the calculated values of Effectiveness for the British tanks against the two Russian ones. The values of Effectiveness have been determined from the kill probabilities given in Tables 1(a) and 1(b), and from estimates of the average rates of fire of the equipments made in accordance with the expression given in AORG Report 6/52. This expression takes account both of the normal rate of aimed fire and of the time taken to switch to a new target when the previous one has been knocked out*; increasing weight is given to the latter as the kill chance increases since relatively more time will be spent in switching from one target to another. The normal rates of fire (R rds/min) which have been assumed for the tanks under consideration are shown in Table 2. It is considered that they are a good estimate of what is likely to be achieved under battle conditions and, if anything, favour the Russian tanks. The average switching times have been taken as 15 seconds for each vehicle, except the JS3. For this tank, in which cramped crew conditions hinder the operation of the fire control system, 23 seconds has been used.

Table 2

Effectiveness : British v Russian Tanks

British tank	Range in yds	Versus JS3 (R=3-4) 122 mm APCBC	Versus T34/85 (R=6-9) 85 mm APBC
Conqueror (R=5-7) 120 mm AFDS	1,000 2,000	1.3 1.4 1.5	1.3 1.5
Conqueror (R=5-7) 120 mm HESH	1,000 2,000	1.4 1.2	1.3 1.1
Conway (R=5-7) 120 mm AFDS	1,000 2,000	1.2 1.3	1.1 1.5
Conway (R=5-7) 120 mm HESH	1,000 2,000	1.2 1.0	1.1 1.1
Charioteer (R=6-8) 20 pr AFDS Mk 3	1,000 2,000	1.0 1.1	1.0 1.1
Centurion 3 (R=7-10) 20 pr AFDS Mk 3	1,000 2,000	1.2 1.4	1.4 1.7

Note : The figures for the Centurion 3 are slightly different from those quoted in an earlier report. This is because more recent figures for the performance of the Russian 85 mm APBC ammunition have been used. Also see footnote to paragraph 3.

* It is worth pointing out that the limited evidence available suggests that the "time into action" is comparable with this switching time.

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10. The values of Effectiveness quoted in Table 2 are the means of the values calculated for the extreme rates of fire. Over the range of rates of fire considered, in no instance is the variation from the mean more than about $\pm 10\%$. Variations in the values assumed for switching times have also been studied, but the differences observed are again not unduly sensitive to slight changes in the figures assumed.

11. Table 3 presents the Effectiveness of the three new British tanks relative to that of the Centurion 3, when opposed to the two Russian vehicles.

Table 3

Relative Effectiveness : Conqueror, Conway
and Charioteer compared with Centurion 3

Tank	Range in yds	As opposed to JS3	As opposed to T34/85
Conqueror 120 mm AFDS	1000	1.2	0.9
	2000	1.1	0.9
Conqueror 120 mm HESH	1000	1.2	0.9
	2000	0.9	0.6
Conway 120 mm AFDS	1000	1.0	0.8
	2000	0.9	0.9
Conway 120 mm HESH	1000	1.0	0.8
	2000	0.7	0.6
Charioteer 20 pr AFDS Mk 3	1000	0.8	0.7
	2000	0.8	0.6

DISCUSSION

General Remarks

12. It can be seen from a comparison of Tables 1(a) and 1(b) that when the British guns fire AFDS ammunition the reduction in the chance of a hit as range increases is less than for the Russian guns. The reason for this is that the British guns fire on flatter trajectories, and range errors therefore have relatively less effect on the chance of a hit. (Table 5 in the Appendix gives the total errors of all the guns concerned). On the other hand, when the 120 mm gun fires HESH ammunition, which is necessarily projected at relatively low velocity, it is less accurate at 2000 yds range than the Russian guns. The net result is that, as range increases, the Effectiveness of the tanks increases when they fire AFDS but decreases when HESH is used. At 1000 yds there is no difference in Effectiveness between the two types of ammunition.

13. At first sight Table 2 shows some apparent anomalies - for example, that the Effectiveness of the Conqueror against the T34/85 is less than that of the Centurion. Such anomalies can usually be resolved by remembering that if a gun has a good performance against any particular tank, a more powerful gun is little more effective; similarly the first gun is little more effective against any lighter enemy tank. An increase in rate of fire or a reduction in switching time is normally advantageous, as either will on the average permit the quicker engagement of successive enemy targets in a particular battle.

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14. These, and a for each British compared with Cent to a range of 1000 independent of the

The Centurion 3

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16. The JS3 i T34/85, and the At the same time the 85 mm enable of the Centurion round the Centu JS3 has a lower which on the av takes account c the Centurion.

The Conqueror

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18. The 1 the 20 pr ar tank. At t the front ar silhouette c On balance against the further sma

19. It i future Russ design. H gun perform to 30% grea queror natu its opponer practically the relativ improvement tank, at 1

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14. These, and similar points, are discussed in detail below; the results for each British tank are examined separately, and the three new vehicles compared with Centurion. For simplicity the discussion will relate primarily to a range of 1000 yards, where the performance of the 120 mm gun is sensibly independent of the type of ammunition used.

The Centurion 3

15. It can be seen from Table 1(a) that at 1000 yds an MDS Mk. 3 round from the 20 pr gun has a chance of about 75% of killing the T34/85. Although the 85 mm gun can defeat the side plates of the Centurion, it is ineffective against its frontal armour and turret, and Table 1(b) shows that the T34/85 has a chance of only about 1 in 3 of killing the Centurion. Round for round the Centurion thus has a considerable advantage over the T34/85. The rates of fire of the two tanks are comparable, and the net result is that the Centurion has an Effectiveness of about 1.4 against the T34/85.

16. The JS3 is much more heavily armoured in all its aspects than the T34/85, and the kill chance with the 20 pr. ammunition drops below 50%. At the same time the improved performance of the 122 mm gun compared with the 85 mm enables it to defeat the front armour and parts of the turret of the Centurion, and the kill chance is increased to about 2/3. Round for round the Centurion is thus at a disadvantage against the JS3. However, the JS3 has a lower rate of fire and longer time into action and switching time, which on the average must be a serious handicap. The measure of Effectiveness takes account of this fact and the net result is to tip the scales in favour of the Centurion.

The Conqueror

17. The 20 pr. gun of the Centurion 3 cannot in general defeat the front armour of the JS3. The Conqueror was designed to meet a requirement for a tank mounting a heavier gun which would have an improved performance against the JS3 and also against any heavier tank which the Russians might subsequently introduce. In fact, the chance of killing the JS3 is about 2/3 for the 120 mm gun, as compared with about 1/2 for the 20 pr. A further advantage of the Conqueror is that its turret is considerably stronger than that of the Centurion. On the other hand, there has been no increase in thickness of the side armour on the hull, while the introduction of the larger gun has necessitated an increase in the silhouette. The reduced vulnerability of the turret on the Conqueror has led to some reduction in the kill chance of the 122 mm gun on the JS3 as compared with that against the Centurion, and round for round the Conqueror has a slight advantage over the JS3. Also its average rate of fire, although somewhat less than that of the Centurion, is still greater than that of the JS3, which adds to its advantage. This is reflected in the figure of Effectiveness of 1.4, which is 20% greater than that of the Centurion.

18. The 120 mm gun cannot defeat any more of the turret of the T34/85 than the 20 pr and it has in fact very little more chance of a kill against this tank. At the same time the 85 mm gun on the T34 cannot defeat the turret or the front armour of either the Centurion or the Conqueror, but the increased silhouette of the latter gives the 85 mm a rather higher chance of killing it. On balance the Conqueror is thus slightly less effective than the Centurion against the T34/85, and its slightly lower average rate of fire gives rise to a further small reduction in Effectiveness.

19. It is difficult to estimate the performance of the Conqueror against future Russian heavy tanks in the absence of any information on their possible design. However, a number of hypothetical designs have been specified with gun performance up to that of the 120 mm British gun, and armour thickness up to 30% greater than that of the JS3. Although the Effectiveness of the Conqueror naturally varies according to the precise characteristics assumed for its opponent, its Effectiveness relative to that of the Centurion remains practically constant at 1.1 - 1.2. Comparison with Table 3 thus shows that the relative Effectiveness of Conqueror and Centurion will not be affected by improvement in the gun performance or armour protection of the Russian heavy tank, at least within the limits considered.

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The Conway

20. The Conway is an up-gunned Centurion, the 20 pr gun being replaced by a 120 mm equipment. The improvement in gun performance has been gained at some cost, the silhouette having been increased and the thickness of the turret reduced. Although the Conway has the same firepower as the Conqueror, its vulnerability is thus greater than that of either the Conqueror or the Centurion.

21. Against the JS3, the Effectiveness of the Conway is the same as that of the Centurion 3, its improved gun performance being offset by its increased vulnerability and lower rate of fire. Against the T34/85, the disadvantages of the Conway relative to the Centurion remain important; but, as noted in para 18, the 20 pr gun is already so effective against the T34/85 that the 120 mm does little better, and the Effectiveness of the Conway is in consequence appreciably less than that of the Centurion.

22. The only advantage derived from up-gunning the Centurion is the ability to defeat the front armour of the JS3. The value of the Conway depends on whether, from tactical considerations, this capability outweighs the disadvantages of increased vulnerability and reduced rate of fire.

The Charioteer

23. The Charioteer is a Cromwell which has been up-gunned to take the 20 pr.* Although it mounts the same gun as the Centurion 3, its armour is much lighter and a hit from either of the Russian tanks has almost a 90% chance of killing it. As a result, its Effectiveness is some 20-30% less than that of the Centurion. Nevertheless, the high chance of killing the T34/85 with the 20 pr gun gives the Charioteer an Effectiveness of unity against the T34/85. Against the JS3 the Charioteer is at a considerable disadvantage round for round, but its superior rate of fire and swiftness of unity average to offset this disadvantage, and it has an Effectiveness of unity against this Russian tank also.

CONCLUSIONS

24. Of the British tanks considered in this memorandum, the best performance against the JS3 is given, as might be expected, by the Conqueror, whose Effectiveness is some 20% greater than that of the Centurion 3. This improvement is due primarily to the better performance of the 120 mm gun against the frontal armour of the JS3. The relative Effectiveness of Conqueror and Centurion is likely to be maintained against any heavier Russian tank. Against the T34/85 the Effectiveness of the Conqueror is no greater than that of the Centurion, since both British tanks are very effective against the lighter Russian vehicle.

25. The Conway is an up-gunned Centurion with a 120 mm gun, and it therefore has the same gun performance as the Conqueror against the front of the JS3. The improvement in gun performance over that of the Centurion has, however, been offset by an increase in vulnerability due to a reduction in armour and an increase in silhouette, and the two tanks have the same Effectiveness against the JS3. At the same time the Effectiveness of the Conway against the T34/85 is some 20% less than that of the Centurion, largely on account of its greater vulnerability. The value of the Conway therefore depends on whether, from tactical considerations, the advantage of being able to defeat the JS3 from the front outweighs the associated disadvantage of increased vulnerability.

* The great superiority of the 20 pr gun over the 75 mm leads to a marked improvement in the performance of the Charioteer as compared with the Cromwell against the two Russian tanks.

26. Although as the Centurion is rather T34/85 and is at disadvantage, it is time more or less

27. The comparison of the Effectiveness of fire ADS or HE the British guns, but these result, the Effectiveness that at 1000 y 120 mm leads to

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26. Although the Charioteer, an up-gunned Cromwell, mounts the same gun as the Centurion 3, its armour is much lighter and comparison with the Centurion is rather unfair. Nevertheless, it has a high chance of killing the T34/85 and is equivalent to this tank. Against the JS3 it is at a considerable disadvantage, round for round, but its superior rate of fire and switching time more or less offset this disadvantage in an extended action.

27. The comparisons given above relate to ranges of up to 1000 yards, where the Effectiveness of the tanks with the 120 mm gun is the same whether they fire APDS or HESH ammunition. At 2000 yards range the accuracy of each of the British guns firing APDS ammunition is greater than that of the Russian guns, but these in turn are more accurate than the 120 mm firing HESH. As a result, the Effectiveness of British tanks at 2000 yds is rather greater than that at 1000 yards when they fire APDS ammunition, but the use of HESH in the 120 mm leads to some reduction in Effectiveness at the longer range.

ACKNOWLEDGEMENTS

28. Acknowledgements are made for the help and data given by the Ordnance Board and by the Fighting Vehicles Research and Development Establishment.

A. V. Longman.

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AORG Report No. 6/52

Tank Effectiveness. A Comparison of the
Theoretical Measure with Observed Battle
Performance and a further Note on Rate of
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APPENDIX

Gun Performance and Errors

1. Table 4 gives the penetration of British homogeneous plate at two ranges and at two angles of attack, of all the AP ammunition relevant to this memorandum. Figures are also shown for the thickness of plate scabbed by the HESH ammunition. The choice of British homogeneous plate is based on the assumption that all tanks carry the best armour protection at present possible, and therefore somewhat favours the Russian tanks.

Table 4
Penetration (mm) of British and Russian Tank Guns

Gun	Range in yds	At normal	At 60° to normal
120 mm AFDS	1,000	446	118
	2,000	406	108
120 mm HESH (thickness scabbed)	1,000	120	163
	2,000	120	163
20 pr AFDS Mk 3	1,000	330	87
	2,000	290	77
122 mm APCBC	1,000	204	73
	2,000	180	64
85 mm APBC	1,000	147	52
	2,000	124	44

Note : The values for the Russian guns are based on best equivalent British APCBC type of projectile and may be over-estimates.

2. Table 5 shows the standard deviation (σ_v) of the total vertical errors, at the two relevant ranges, of all the guns mentioned in this report when the ranges are estimated by range-finder. The range estimation error is assumed to have a standard deviation (in yards) of $19r^2$ (r = range in thousands of yards). The horizontal errors, which are independent of the means of range estimation, are also presented (σ_h).

Table 5
Gun Errors (ft) of British and Russian Tank Guns

Gun	σ_v		σ_h	
	1,000 yds	2,000 yds	1,000 yds	2,000 yds
120 mm AFDS	1.43	3.08	1.42	2.84
120 mm HESH	1.35	6.64	1.23	2.47
20 pr AFDS Mk 3	1.63	3.46	1.63	3.26
122 mm APCBC	1.59	4.89	1.69	3.38
85 mm APBC	1.69	5.05	1.64	3.28

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Distribution

SA/LAC	
DMI	8
DGMT	1
Royal Military College of Science	2
RAC Centre	1
STT	1
DWD	1
DRAC	2
ORS (BAOR)	2
ORS (FARELF)	2
Ministry of Defence	6
DRP Staff	
Ministry of Supply	1
TOB	
IDSIR(D)	1
DGFV	1
DWR(D)	1
FVRDE	1
FVED	2 (1 for AR)
ADE	1
TPA3/TIB	2 (1 for CT2)
Defence Research Liaison, Canada	2
British Joint Services Mission, Washington	6
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